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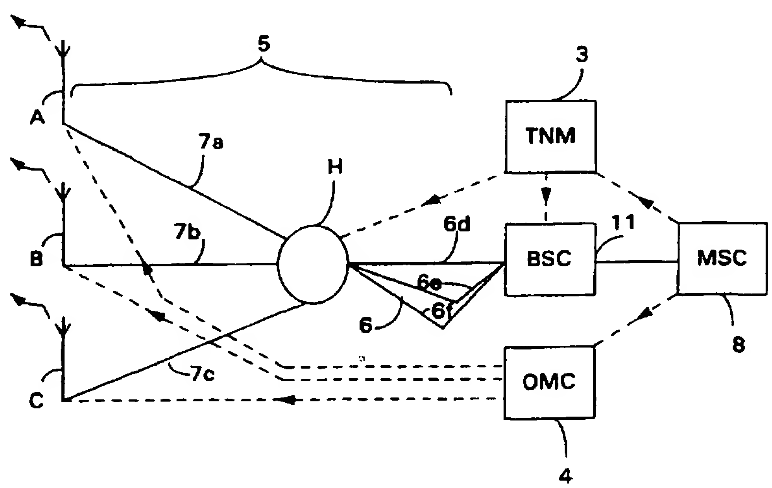

(57) Abstract

A cellular radio system comprises radio base stations (A, B, C), each having an allocated number of radio channels. Each radio base station is connected to the rest of the network (BSC, MSC) by a branched network (5, 7a, 7b, etc.). At the branch point H an intermediate switch is provided for connecting channels in the trunk portion (5) to channels in the branches (7a, 7b, etc.). The capacity of the trunk link (5) is less than the total capacity of the base stations (and of their associated branch links (7a, 7b, 7c)). At times when one or more of the base stations (A, B, C) have surplus capacity, that capacity is disabled so that the capacity of the trunk link (5) is not exceeded. The capacity of each base station (A, B, C) may be varied according to predicted or actual demand, provided that the total (non-disabled) capacity of the base stations (A, B, C) does not exceed that of the trunk link (5).

MOBILE RADIO SYSTEMS

This invention relates to mobile radio systems. The invention will be described primarily in relation to cellular radio networks. However the invention is also applicable to other mobile radio systems, such as private mobile radio (PMR) systems.

In a typical cellular radio network a number of radio base stations are located throughout the area in which radio coverage is required, in order to allow mobile units throughout that area to be in radio communication with the fixed part of the network via one of the radio base stations. The radio base stations comprise radio transceivers for establishing radio communication with nearby mobile units. Several radio channels are provided to allow simultaneous communication with several mobile units. These radio channels may for example be separate time slots in a time-division scheme, and/or different radio frequencies. The radio base stations are themselves physically connected by fixed links to a switching centre, and thereby a communications link can be activated between two mobile units via respective radio base stations, or between a mobile unit (again via a radio base station) and a fixed telephone network e.g. PSTN, or other cellular radio system, or other telecommunications network.

The radio base stations require control functions to establish radio communication with mobile units, and to carry out various other functions to determine which mobile units are within its area of coverage in order to direct incoming calls to the correct mobile unit, and to arrange handover of calls should a mobile unit move during the course of a call from the area served by one base station to that served by another. Such control functions include commands to the radio base stations to communicate with a mobile unit on one of its allocated channels, including instructions as to when to start and terminate the call, or to carry out handover processes.

In the GSM (Global System for Mobile radio) standard, these control functions of the radio base stations are functionally, and usually physically, separate from the transceivers they control. The control functions are performed by a "Base Site Controller" (BSC) controlling the radio transceivers of several radio base stations, (known in the GSM system as "Base Transceiver Sites" (BTS)),

functions are carried out at the base transceiver site) a similar problem arises in the fixed links between the base stations and the main mobile switching centre (MSC), which serves many radio base stations. The fixed links also form a branched network and there can be over provision of capacity in the trunk common to several branches for the same reasons.

International patent specification WO94/00959 (Nokia) describes an arrangement in which a synchronous digital hierarchy (SDH) network comprising a loop serves a number of individual microcell base transceiver sites. At each base transceiver site on the loop there is an Add-drop multiplexer (ADM)which allows the channels relevant to the base transceiver site or sites served by the multiplexer to be extracted. Since the SDH loop is common to all the base transceiver sites, and any of its channels may be allocated to any of the base transceiver sites according to demand, fewer channels are required in the SDH system than the total combined capacity of the base stations.

However, this system suffers from a number of disadvantages. Firstly, the basic element of an SDH carrier, known as STM-1, has a capacity of 155 Mbit/s. A typical microcell site requires only 320 kbit/s. Consequently, to use the SDH network to capacity, more than 500 microcell sites would have to be served by each loop if the total combined capacity of the base stations is to be greater than the capacity of the SDH system. This is an inefficient use of the capacity of the SDH system, as each microcell on the loop has to be fed by two 155 Mbit/s connections, in order to supply a 320 kbit/s capacity. Moreover, five hundred microcell sites would serve a large area, and to have a large area served by a single loop would leave it very vulnerable to any faults - two faulty links could isolate all five hundred microcells. Also, the physical size of an add-drop multiplexer is very much greater than that of the microcell base site electronics itself, so such a microcell/ADM combination would be less convenient to install, and have greater visual impact. Moreover, the arrangement described in the above-mentioned patent specification has a single base site controller (BSC) and mobile switching centre serving all the base transceiver sites. This requires control signals to be transmitted over the SDH loop between the BSC and each BTS. A channel for such control signals, to control handover etc, must be available to each base transceiver site, even when not in use, so that a handover can be

number of channels used by the trunk communications link serving the intermediate switch.

This arrangement allows a trunk link, having a lower capacity than the combined capacities of the radio base stations it serves, to be used between an intermediate switch, located at the point where the routes to the individual base stations branch, and the rest of the network. The branched layout is more efficient than a loop, both in terms of total length of the individual links, and because the capacity requirements are lower on the more remote branches. Furthermore, the branched layout is suitable for use by a plesiochronous digital hierarchy (PDH), as an alternative to the SDH, as will be described.

In the preferred embodiment, the trunk communications link connects the intermediate switch to a base site controller where the main base station control functions still take place. In one arrangement, one or more first intermediate switches are connected by their respective trunk communications link to a further one of the intermediate switches, the further intermediate switch thereby serving the base stations also served by the one or more first intermediate switches. The further intermediate switches may themselves also serve one or more further base stations directly.

In an enhancement of the invention, the introduction of a limited switching capability at a branch point also allows the channels to be routed selectively over common physical trunk links between the branch point and the rest of the network, thereby providing some safeguard against total loss of the links. The radio base stations are not dedicated to individual channels over the trunk link between the intermediate switch and the rest of the network, so in the event of the loss of one of the physical trunk links, each radio base station can have some of its channels routed over the remaining physical link or links, thereby allowing all radio base stations to continue operating, albeit probably with lower capacity.

Preferably, each radio base station has associated control means to selectively enable and disable one or more of its available radio channels (and associated channels in the communications link) such that the total number of enabled radio channels does not exceed the number of channels in the trunk link, and the intermediate switch has means to allocate the channels in the trunk link to

The system may be arranged such that any spare traffic capacity is distributed in the radio and transmission networks.

Preferred embodiments of the invention will be further described with reference to the accompanying drawings in which:

Figure 1 shows a typical pattern of traffic demand in three radio base stations;

Figure 2 shows a prior art cellular radio system;

Figure 3 illustrates a simplified cellular radio system according to the preferred embodiment of the invention;

Figure 4 shows a more complex transmission network;

Figure 5 shows an architecture for the monitoring and control system of the cellular radio network; and

Figure 6 shows a timeslot allocation pattern in use on one of the communications channels of a trunk link of the simplified system illustrated in Figure 3.

In order to understand the invention, it is useful to first consider the traffic demand in an illustrative system. The problem has been greatly simplified for the purposes of this illustration, but the underlying principles would apply in a more complex system having many base stations and more variable loadings.

Figure 1 shows illustrative traffic levels for three radio base stations of an illustrative cellular radio system. Each radio base station (BTS) A, B, C has a maximum capacity of 45 communications channels, but these radio base stations do not all require that maximum capacity at the same time. In a morning period t1 (from T0 to T1, 7 a.m. to noon) the radio base station B requires its full capacity of 45 channels, whilst radio base stations A and C require 30 and 15 channels respectively. In an afternoon period t2 (from T1 to T2: noon to 6 p.m.) the radio base station A requires its full capacity of 45 channels, whilst radio base stations B and C require 30 and 15 channels respectively. In an evening period t3 (from T2 to T3: 6 p.m. to midnight) all three radio base stations A, B, C require 30 channels. In a night period (T3 to T4: midnight to 7 a.m.) the radio base station C requires its full capacity of 45 channels, whilst radio base stations A and B each require only 15 channels.

Figure 2 shows a basic layout in which the three radio base stations (base transceiver sites BTS) A, B and C are connected to a switching centre MSC

that the physical links illustrated will in practice be embodied by a system of links having a built-in redundancy, in order to make the system more robust. A group of base site controllers 11a, 11b ... 11g etc are operated under the control of a mobile switching centre (MSC) 8. The mobile switching centre 8 and each of the base site controllers 11a etc may communicate with the mobile switching centre, 8 by means of a communications network such as a synchronous digital highway (SDH) loop. Capacities required by the individual base site controllers justify the use of a synchronous digital hierarchy loop arrangement at this level in the network, but not in the links to individual base stations. As a precaution against of the failure of the mobile switching centre 8, a second mobile switching centre 18 is also connectable to the base site controllers 11 to 11g, as well to its own dedicated base site controllers 12a, etc to 12n. Similarly, should the second mobile switching centre 18 fail, then the base site controllers normally served by that mobile switching centre can be controlled by the mobile switching centre 8. Each base site controller and mobile switching centre is connected into the synchronous digital hierarchy network by means of an add-drop multiplexer ADM, which extracts the traffic intended for the individual base site controller from the network and adds, to the SDH loop, traffic originating from that BSC. It should be noted that the add-drop multiplexers are controlled in order to extract the relevant signals from the multiplex carried on the main loop. Moreover, if a synchronous digital hierarchy is in use, the minimum amount which can be extracted from the synchronous digital hierarchy system is determined by the capacity of an individual module of the hierarchy, known as "STM1". The minimum capacity of a complete SDH system, on which such STM1 modules are carried, is of an appropriate size to serve the area covered by an individual mobile switching centre.

Each individual base controller (BSC) serves a number of base transceiver sites. This is illustrated specifically only for one base site controller 11, but it will be appreciated that all the other base site controllers 11a - 11g serve a similar arrangement of base transceiver sites. Each base site controller may serve one or more main hubs. As shown in Figure 4, the base site controller 11 serves two hubs H1 and H4. The branched structure of the hierarchy may take may forms, of which two are illustrated in Figure 4. In the first example, serving base transceiver sites A, B, C and D, base transceiver sites C and D are connected to a hub H3 which has a dedicated respective trunk link 23 which is connected to a second hub

then reconstitute the multiplexing, stage by stage, for onward transmission to the next element around the loop. The architecture of the present invention is particularly appropriate to PDH, but SDH could be used with little impairment.

Figure 5 shows the basic arrangement of various control systems which together cooperate to maximise the use of the radio resource and transmission network resources available. The transmission resource 3 and operation and maintenance centre for the radio resource (4) respectively control the transmission network (5) and radio network (i.e. base transceiver A, B and C). These both supply inputs to a statistical monitoring system 9, which also has data on regular daily, weekly etc demand for the system. Input from the traffic statistics system, the transmission network manager 3, and the operation and maintenance centre (4) are applied to a transmission capacity controller 10, which in turn control the transmission network manager 3 and operation and maintenance centre 4. The transmission capacity controller 10, which will be associated with the mobile switching centre 8, monitors both the radio and fixed parts of the system to detect faults and usage of the system, and in turn controls them, for example in order to establish links between individual elements of the fixed system, making use of the flexibility of the fixed network and to switch radio transceivers on and off in the radio network in accordance with the capacity of the part of the transmission network feeding their respective base stations.

By separating this function from the routine operation of the mobile switching centre, (which operates to provide radio capacity, and also fixed network capacity, on demand), the system can better cope with individual demand cases. In particular, at times when there is spare capacity in the system, the transmission capacity controller arranges that this spare capacity is spread evenly around the system, so that extra capacity can be switched in by the OMC 4 and transmission network manager 3 to any part of the radio network, using spare capacity allocated to it, without requiring intervention from the transmission capacity controller. This allows individual call set ups and handovers to be handled promptly, while the transmission capacity controller can monitor and deal with incipient large scale capacity problems on a longer time scale.

Figure 6 shows the timeslot allocations on one of the three channels 6d, 6e, 6f for the four periods t1, t2, t3, t4 for the three base transceiver sites A, B and C of Figure 3. Each channel has 32 time slots (numbered 0 to 31) including a

transceiver site C, thereby allowing base transceiver site C to use all its 45 radio channels during the overnight period t4, whilst leaving base transceiver site B with 15 time slots. base transceiver site A also requires only fifteen time slots for the overnight period t4, so fifteen time slots (17 to 21 from channel 6d, etc.) become spare. These spare time slots can be allocated to other base transceiver sites (not shown) or held in reserve for contingencies, such as the failure of one of the channels 6d, 6e, 6f in the trunk link 6.

Finally, at time T0, thirty of the time slots allocated to base transceiver site C are reallocated to base transceiver site B, and the fifteen spare timeslots are allocated to base transceiver site C, ready for the cycle to repeat again.

The channels 6d, 6e, 6f making up the trunk link 6 may be routed separately, over different physical routes, in order to safeguard against simultaneous failure of the entire link 6. The timeslots allocated to each base transceiver site are distributed amongst the channels 6d, 6e, 6f such that each base transceiver site has some timeslots on each channel. This ensures that should one of the channels 6d, 6e, 6f fail, some capacity is maintained for each base transceiver site A, B, C.

In the morning period t1, base transceiver site A has only fifteen timeslots available on the link 5 to support its forty-five radio channels. The remaining thirty radio channels are "busied out", i.e. the base site controller is instructed not to allow the base transceiver site A to operate on those remaining radio channels, thereby limiting the number of mobile units which can be put into communication with the network through that base transceiver site A.

This illustrative example includes a number of spare timeslots in the overnight period t4. Each channel has thirty traffic timeslots, and thus timeslots are only available in multiples of thirty. In a typical system there would be more than three base transceiver sites, and it will be easier to match the timeslot capacity to the demand. However, the availability of some spare timeslots can be useful to ensure robustness of the system should one of the channels 6d, 6e, 6f fail, since some of the calls which would otherwise be lost can be transferred to the spare timeslots on the remaining line.

It is possible that at certain times of day a base transceiver site has no demand at all, or what demand there is can be covered by neighbouring base

allocated to the first base transceiver site until the call is terminated or handed over, and the channel then reallocated to the second base transceiver site.

In a variant of this system, the levels of demand on the various base transceiver sites A, B and C are monitored, and channels in the transmission network are allocated to the base transceiver sites as required. In this arrangement, channels which are not currently in use are not allocated to any individual base transceiver site, but form a "floating reserve", available for use by any of the base transceiver sites A, B, C.

If a mobile unit requires a handover from one base transceiver site A to another base transceiver site B served from the same branch point, this would not be possible if all the channels on the branch point to base site controller link 5 are in use, because although there are radio channels available at the base transceiver site B to which handover is to take place, those channels are "busied out" because there are no channels available for them in the fixed link. A channel will, of course, become available as soon as the call is dropped as a result of the failure of the first base transceiver site A to hand over before signal quality deteriorates to a level where the call has to be dropped. However this channel would become available to any mobile unit attempting to make a call, and the mobile unit from which handover was unsuccessfully attempted would have to start the call initiation process again, and would have no more chance of obtaining that channel than any other mobile unit - in fact rather less, since another mobile unit which has already started a call attempt is likely to seize the channel first. It is desirable to maintain existing calls, in preference to failing them in order to allow further call attempts to succeed, (provided that all the calls are of the same priority). In order to do this the base site controller BSC, recognising that a handover is required between two base transceiver sites A, B served from one branch point, transfers the channel (e.g. 6a) in the branch point-to-BSC link 6 allocated to the call that the mobile unit is engaged on from the first radio base station A to the second base transceiver site B at the instant of handover.

The preferred embodiment has been described in relation to the architecture and terminology of the GSM standard for cellular radio systems. However it is possible to use a similar system for other cellular radio systems, and also for private mobile radio networks. In contrast to the embodiment illustrated

CLAIMS

1. A mobile radio system for serving a plurality of mobile radio stations, the system comprising: a plurality of radio base stations for communicating with the mobile radio stations, and each having an allocated number of radio channels;

one or more trunk communications links;

each trunk communications link serving a respective intermediate switch serving a plurality of radio base stations;

each radio base station being connected to its serving intermediate switch by a communications link having at least the same number of channels as the radio base station has allocated radio channels;

each trunk communications link having fewer channels than the total number of radio channels of the plurality of radio base stations served by its respective intermediate switch ; and

radio resource control means for controlling the radio base stations so that the total number of channels in use by each trunk communications link is greater than or equal to the number of radio channels in use by the base stations it serves.

2. A mobile radio system according to claim 1, wherein one or more first intermediate switches connected by their respective trunk communications link to a further one of the intermediate switches, the further intermediate switch thereby serving the base stations also served by the one or more first intermediate switches.

3. A mobile radio system according to claim 1 or claim 2, wherein the communications links are arranged to operate as a plesiochronous digital hierarchy.

4. A mobile radio system according to claim 1, 2 or 3 in which each radio base station has associated control means to selectively enable and disable one or more of its available radio channels and associated communications link channels such that the total number of enabled radio channels does not exceed the number of channels in the trunk link and the intermediate switch has means to allocate the channels in the trunk link to calls using those channels in the communications link

10. A method of operating a mobile radio system comprising a plurality of radio base stations each capable of transmitting to, and receiving radio signals from, mobile radio stations on a number of radio channels, each radio base station being connected to an associated intermediate switch by an associated communications link having at least the same number of channels as the radio base station has allocated radio channels; and one or more trunk communications limks, each trunk communications link serving a respective intermediate switch and having fewer channels than the total number of radio channels of the plurality of base stations served by its respective intermediate switch,

the method comprising the steps of controlling one or more of the radio base stations connected to an intermediate switch, and their associated communications links, so that the total number of radio channels in use by the radio base stations served by an intermediate switch is less than or equal to the number of channels used by the trunk communications link serving the intermediate switch.

11. A method according to claim 10, wherein the communications links are operated as a plesiochronous digital hierarchy.

12. A method according to claim 10 or 11 comprising the steps of selectively enabling and disabling one or more of the radio channels available to the radio base stations, such that the total number of enabled radio channels does not exceed the number of channels in the trunk link, and allocating the channels in the trunk link to calls using those channels in the communications link associated with the currently enabled radio channels.

13. A method according to claim 10, 11 or 12, wherein a communications channel in the trunk link is allocated to a radio base station in response to a request to establish radio communication between that radio base station and a mobile radio unit.

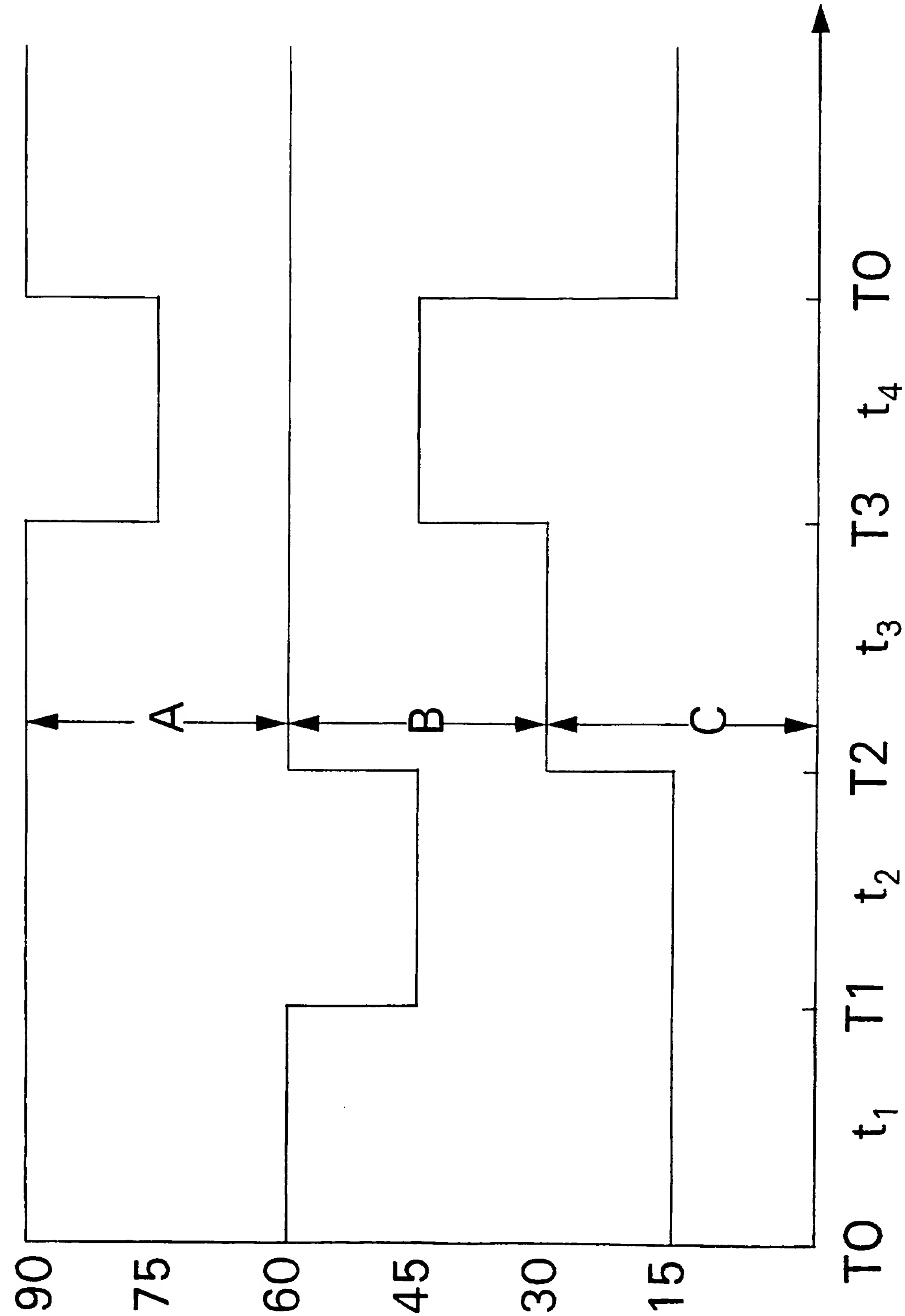

Figure 1

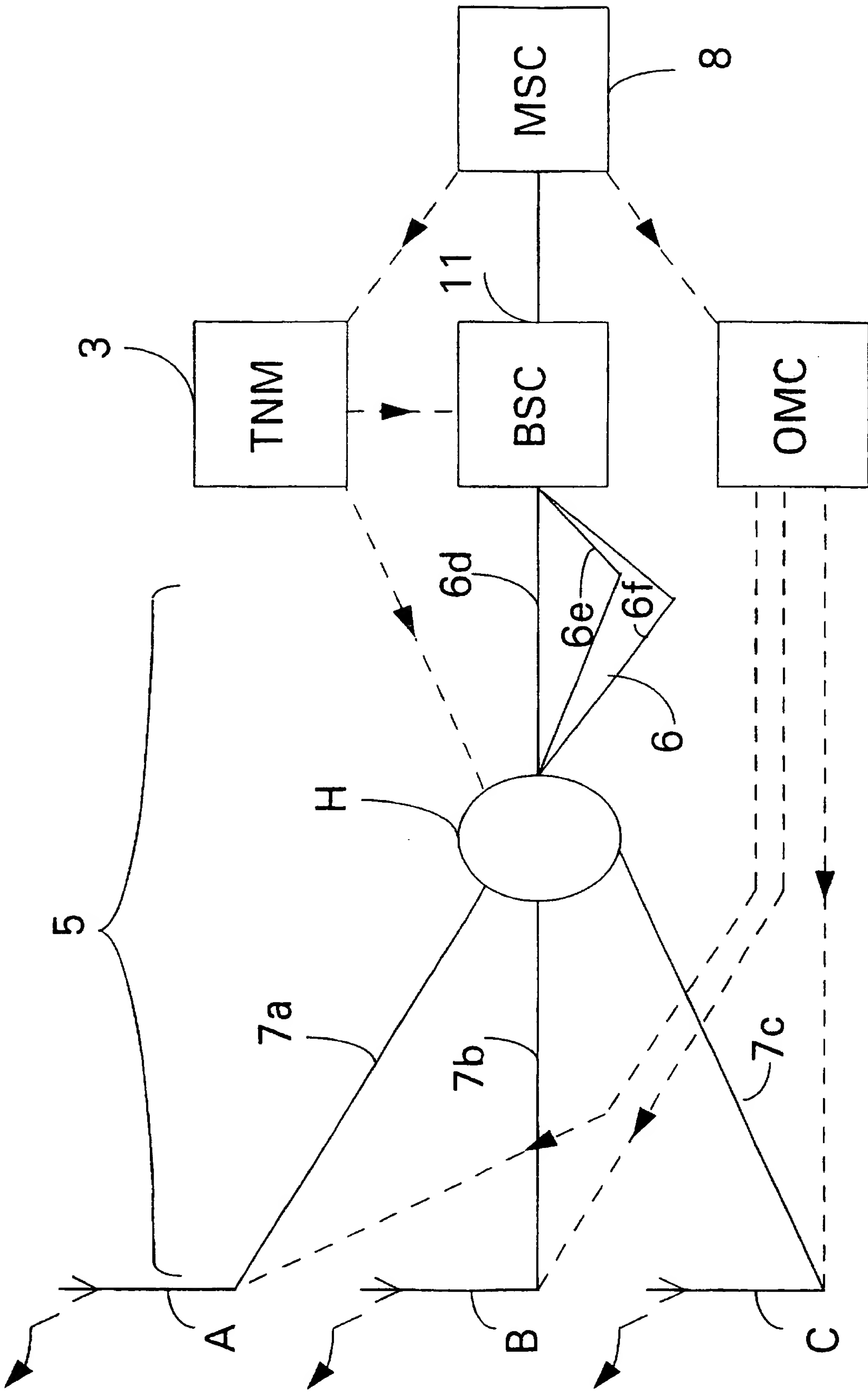

Figure 3

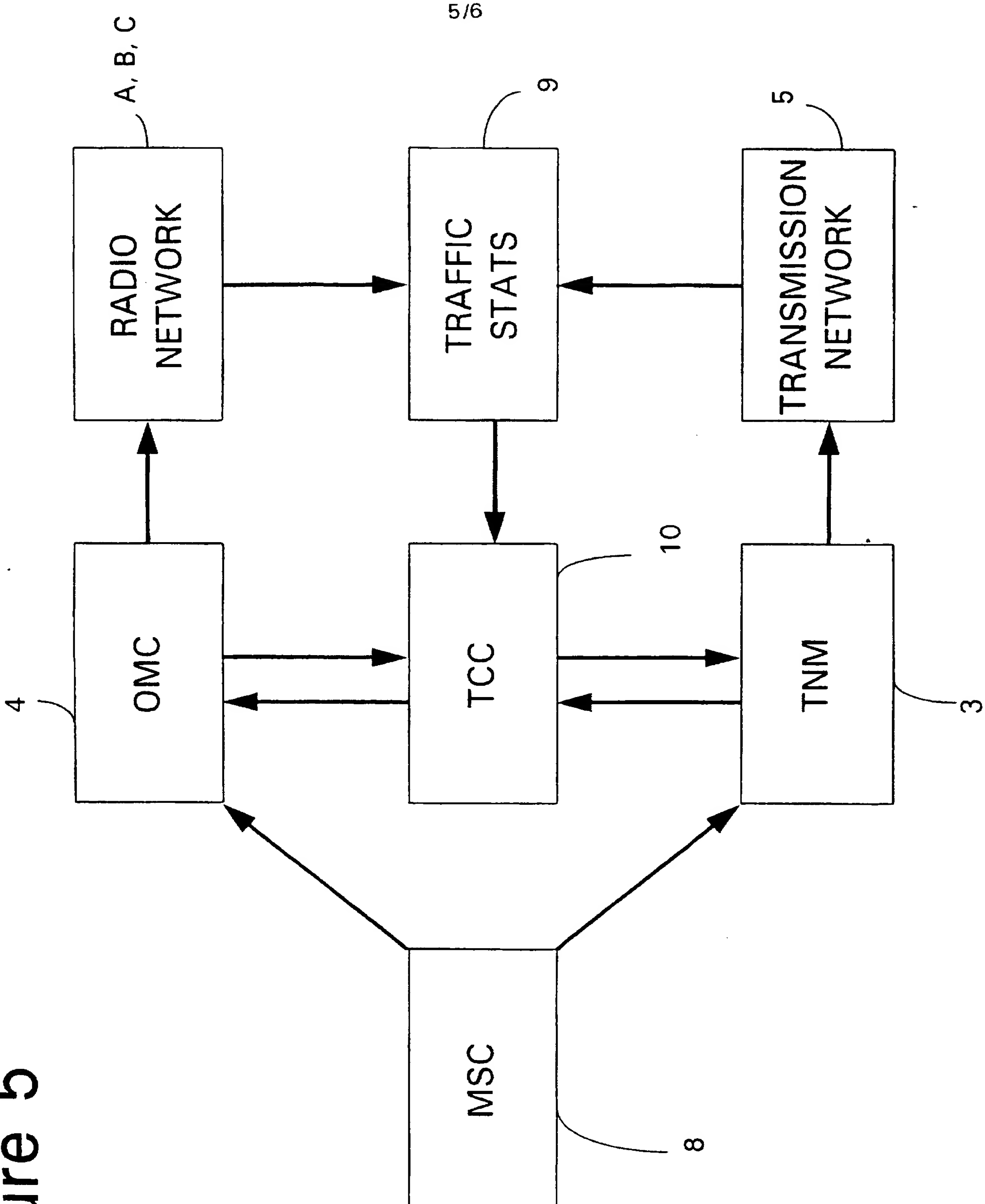
RADIO NETWORK
A, B, C
TRAFFIC STATS
9
TRANSMISSION NETWORK
5
OMC
4
TCC
10
TNM
3
MSC
8

Figure 5

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 96/03056

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H04Q7/30

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H04Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 94 00959 A (NOKIA TELECOMMUNICATIONS OY ;TAHKOKORPI MARKKU (FI)) 6 January 1994 see page 5, line 31 - page 7, line 23 see page 8, line 4 - page 9, line 30 ---	1,4,6,8, 10,12, 13,15
A	WO 93 13632 A (PEITZ GMBH) 8 July 1993 see page 1, line 32 - page 2, line 27 see page 4, line 23 - page 6, line 6 see page 9, line 13 - page 12, line 23; figures --- -/--	1,4,6,8, 10,12, 13,15

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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1

Date of the actual completion of the international search	Date of mailing of the international search report
3 June 1997	13.06.97
Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	**Authorized officer** Janyszek, J-M

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
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